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NEW BARNACLE RECORDS (CIRRIPEDIA, THORACICA)

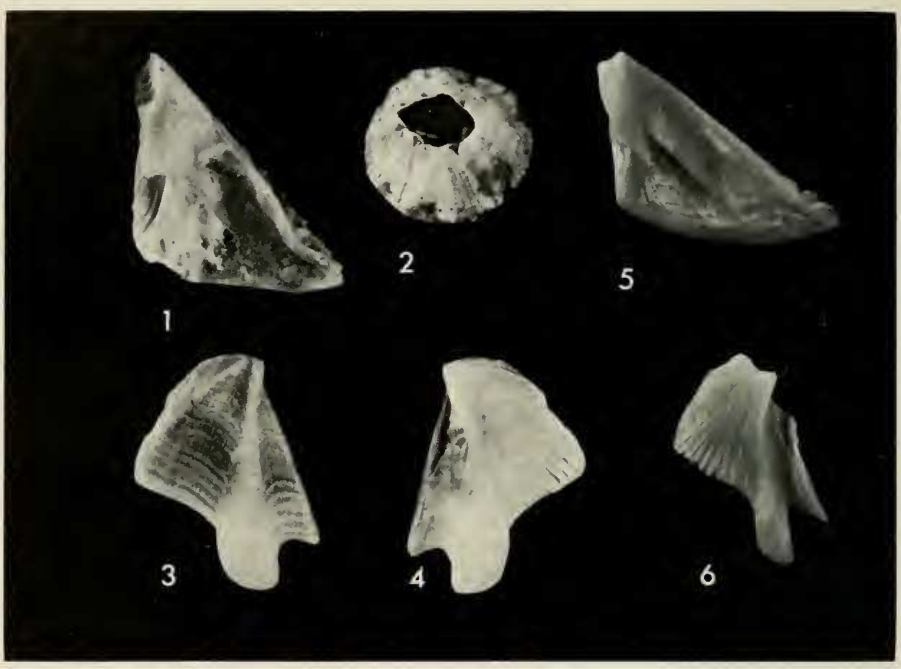
By

Victor A. Zullo, Dea B. Beach, and James T. Carlton
California Academy of Sciences, San Francisco, California 94118

Balanus amphitrite amphitrite Darwin, 1854.
(Figures 1–4.)

In discussing the introduction of *Balanus improvisus* Darwin to the Pacific Coast of North America, Carlton and Zullo (1969) noted that although this species was relatively common in collections dating back to 1853, no specimens of *B. amphitrite amphitrite* were found in collections made prior to 1939, when it was first observed by F. L. Rogers in San Francisco Bay (Henry, 1942). The establishment of *B. improvisus* on the Pacific Coast appears to be tied to the commercial importation of the North American East Coast oyster, *Crassostrea virginica* (Gmelin). Both barnacles are frequent epizooites of this oyster, but as *B. amphitrite amphitrite* is a relatively recent addition to the fauna of the East Coast as well, Carlton and Zullo concluded that its absence in early Pacific Coast collections reflected a similar absence on the East Coast. However, further inquiry into the history of the Pacific Coast oyster industry has revealed that all importations of *Crassostrea virginica* were from areas north of Cape Hatteras, North Carolina (the northern range limit of *B. amphitrite amphitrite*), thus virtually eliminating this oyster as a vehicle of introduction for *B. amphitrite amphitrite*.

While processing miscellaneous collections of barnacles for the Academy of Natural Sciences of Philadelphia (ANSP), two lots of *B. amphitrite amphitrite* were found that had been obtained from the California coast prior to 1939. This material, collected by Charles R. Orcutt and originally identified by Henry A. Pilsbry, consists of four specimens with opercular valves from La Jolla, California, and of a single, large (20 millimeter basal diameter) specimen from San Diego Bay, California. Both lots bear the number "158/428", but no date of



FIGURES 1–4. *Balanus amphitrite amphitrite* Darwin. Figure 1, scutum, height 4 mm.; figure 2, shell, greatest diameter 20 mm.; figures 3–4, terga, height 4 mm. (Figures 1, 3, 4, La Jolla, California; figure 2, San Diego Bay, California). FIGURES 5–6. Opercular valves of *Balanus improvisus* Darwin, CAS locality 41227, Delta Mendota Canal, California, height of scutum and tergum 3.8 mm.

collection. Dr. Robert Robertson and Nancy Rulen of the Philadelphia Academy were kind enough to search their records, and were able to provide the following data:

> ANSP no. 2257. La Jolla, California, C. R. Orcutt collector, donated by the U. S. National Museum and cataloged December 6, 1921.
>
> ANSP no. 2426. San Diego, California, C. R. Orcutt collector, December 9, 1927.

The apparent establishment of *B. amphitrite amphitrite* in southern California by at least the early 1920's and in the late 1930's in northern California is likely attributable to transport by ships. Its occurrence may eventually be placed considerably earlier than this, for it had already arrived in Hawaii by the early 1900's (Pilsbry, 1907, p. 190). *Balanus amphitrite amphitrite* is restricted to certain estuarine parts of the San Francisco Bay complex where mean annual temperatures are highest, but even in these areas Newman (1967) has noted that the temperature regime is clearly suboptimal for this subspecies. If the establishment of *B. amphitrite amphitrite* in San Francisco Bay was

indeed later than in southern California, the delay may be explained by the paucity of suitable environments for successful colonization.

Balanus eburneus Gould, 1841.

(Figures 8–15.)

Balanus eburneus, whose natural range includes the Atlantic coasts of North America and northern South America, the Caribbean Sea, and the Gulf of Mexico, has been introduced by shipping to various parts of the world. Known introductions, emphasizing those in the Pacific Ocean, were summarized by Matsui *et al.* (1964) and Utinomi (1966). Definite Pacific localities include Balboa, in the Bay of Panama, eastern Pacific, the Hawaiian Islands, and the Japan Sea coast of central Japan. Weltner (1897) reported *B. eburneus* on *Fasciolaria* with *B. amphitrite* from Manila in the Philippines, but this identification has not been corroborated.

A sample in the collection of the Department of Invertebrate Zoology of the California Academy of Sciences (CAS) taken by Mr. Vern Brock in July, 1967, from between Ansala and Vera islands in Eniwetok Atoll in the Marshall Islands was found to contain several individuals of *B. eburneus* in association with *B. amphitrite amphitrite.* These specimens represent the first record of *B. eburneus* from islands of the central West Pacific, and no doubt reflect the heavy traffic in American shipping to that area since the Second World War. The occurrence of this Atlantic American species at Eniwetok suggests that other highly frequented ports in the central Pacific islands might also harbor successfully introduced populations of *B. eburneus.*

This species was also discovered recently at another, albeit more likely, locality in the western Atlantic. Mrs. Joleen Gordon, in the course of an ecologic study of Bermuda barnacles during the summer of 1967, found *B. eburneus* to be a common member of that fauna in association with *B. amphitrite amphitrite* and *Chthamalus stellatus thompsoni* Henry.

The barnacle fauna of the Bermudas was investigated most recently by Henry (1958) on the basis of collections made by T. A. and Anne Stephenson in the early 1950's. *Balanus amphitrite hawaiiensis* Broch (= *B. amphitrite amphitrite*) and *Chthamalus stellatus thompsoni* were reported there for the first time, but *Balanus eburneus* was not found. Judging from the abundance of *B. eburneus* and its association with the above-mentioned subspecies as seen in 1967, it is possible that this species has been introduced to the Bermuda fauna since the date of the Stephensons' survey.

Balanus improvisus Darwin, 1854.

(Figures 5–7.)

A living population of *B. improvisus* was discovered in December, 1962, on the concrete lining of a section of the Delta-Mendota fresh water irrigation

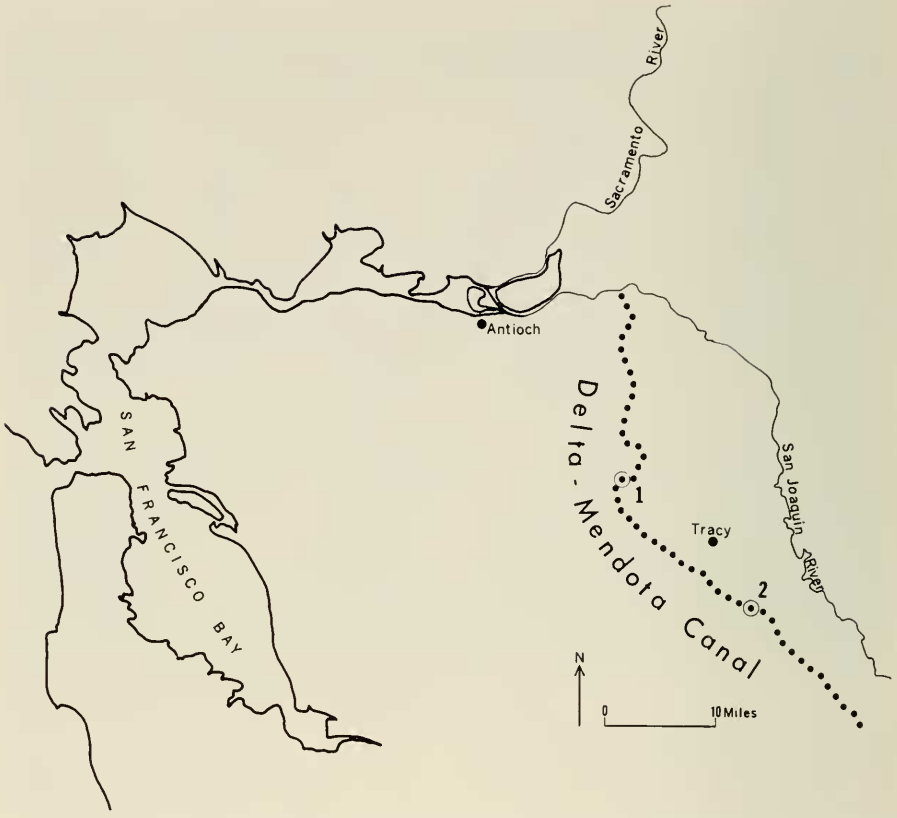


Figure 7. Relationship of Delta-Mendota Canal system to the San Francisco Bay-Delta area. Numbers indicate Tracy Pumping Plant (1) and collection site of *Balanus improvisus* (2).

canal in central California. The barnacles, collected by G Dallas Hanna and Allyn G. Smith of the California Academy of Sciences (CAS locality 41227), were taken at mile post 20.62, or more than 20 miles downstream from the Tracy Pumping Plant, which is about 9 miles northwest of Tracy, San Joaquin County, California (figure 7). This section of the canal was discussed previously by Hanna (1966, p. 40, figs. 30–31) with respect to the phenomenal infestation of the Asiatic fresh water clam *Corbicula manilensis* (Philippi). The occurrence of barnacles in the canal was noted by Prokopovich (1968, p. 53, photograph 48).

Irrigation water is pumped into the Delta-Mendota Canal by the Tracy Plant via a 2.3-mile-long canal from the Old River Channel of the San Joaquin River. This intake is well over 25 miles from the established salt water barrier of the Sacramento-San Joaquin estuary in the vicinity of Antioch, California.

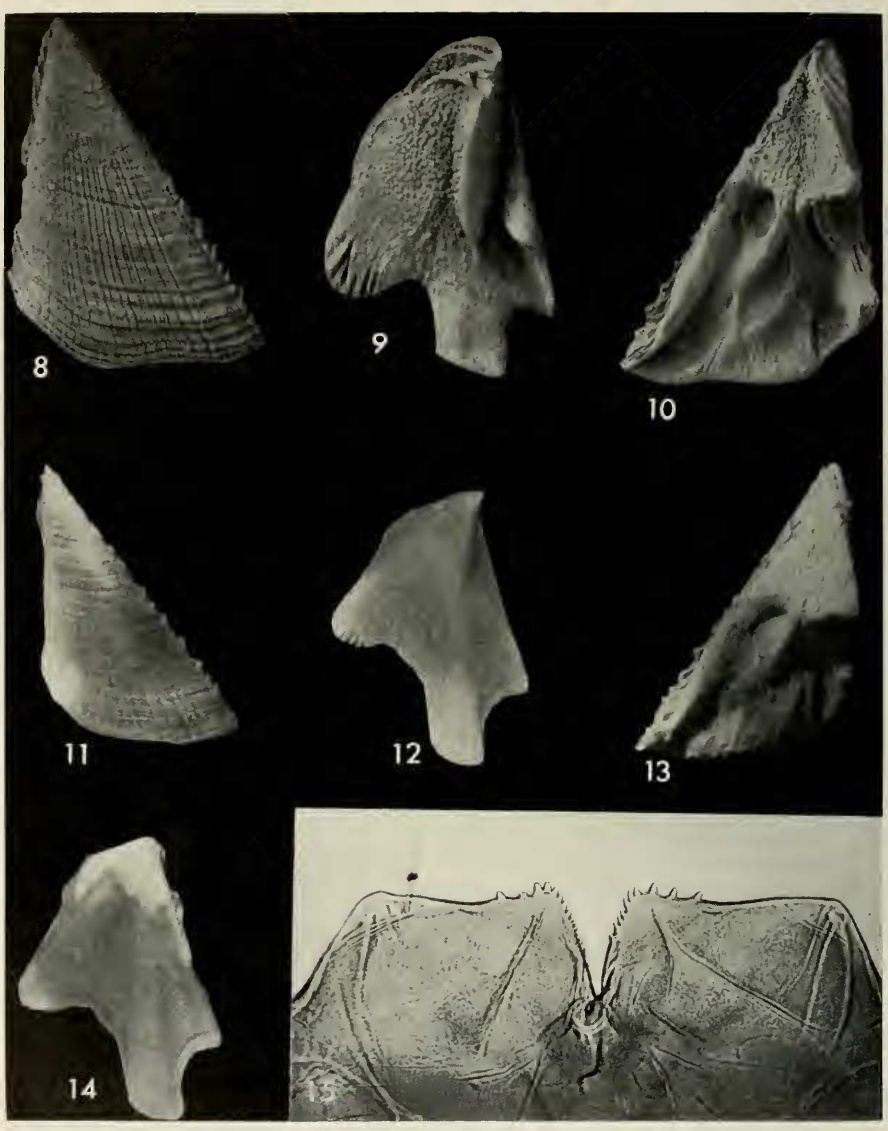
Continuing water quality analyses made at the pumping plant indicate that total dissolved solids do not exceed 500 parts per million (0.5 parts per thousand) at the canal intake.

Although a few species of barnacles are known to live in river estuaries where salinities are negligible for most of the year, there has been only one other report of an apparent occurrence in totally fresh water (Shatoury, 1958; *B. amphitrite* in a cement irrigation holding tank 64 kilometers south of the mouth of the Nile Delta). On the basis of observational and experimental data, it has been assumed that euryhaline barnacles, such as *B. improvisus* and *B. eburneus,* can exist in fresh water as adults provided that higher salinities prevail in the area during larval spawning and settlement. These outlying populations are apparently unable to reproduce, and must rely, therefore, on larval recruitment from breeding populations in higher salinities downstream. The larvae can be transported upstream in the encroaching salt wedge during the dry season, provided that this season (usually summer months) corresponds to spawning season.

Laboratory studies of the salinity tolerances of stage I and II nauplii of *B. balanoides* (Linnaeus), *B. balanus* (Linnaeus), and *B. crenatus* Bruguière were made by Barnes (1953), and Crisp and Costlow (1963) investigated the effects of varying salinities on the developing eggs and early naupliar stages of *B. amphitrite amphitrite* Darwin, *B. eburneus,* and *Chelonibia patula* Ranzani. The results from these two studies agree rather closely. Cytolysis of eggs was observed in all three species examined by Crisp and Costlow at salinities of 10 parts per thousand or less, regardless of temperature. Early stage nauplii of both studies died in salinities of 5 parts per thousand or less after only slight exposure, and could not withstand prolonged exposure to salinities below 10 parts per thousand. There was, however, some indication that larvae hatched from embryos developed at lowered salinities were better adapted to brackish conditions.

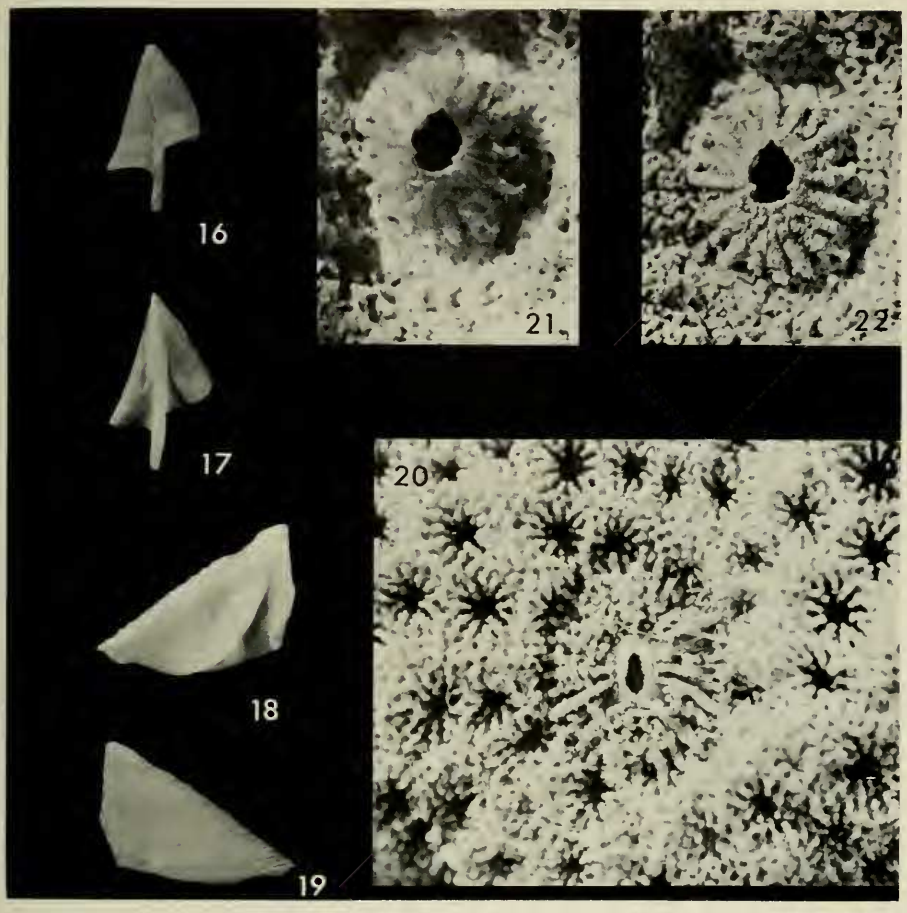
The survival ability of *B. improvisus* larvae in lowered salinities may be greater than that of other estuarine barnacles. Mohammad (1962), in a field and laboratory study of the distribution of barnacle larvae in Newport River, North Carolina, indicated that *B. improvisus* larvae could tolerate salinity as low as 0 parts per thousand, whereas the lower limit for those of *B. eburneus* was about 8 parts per thousand. If larval salinity tolerance were the limiting factor in the distribution of barnacles in estuaries, then *B. improvisus* should be expected in fresh water. However, this is not the case under natural conditions, suggesting that other factors are also limiting.

The only readily apparent physical difference between the two fresh water localities cited here and natural estuarine habitats is direction of current flow. Under natural conditions, larvae must counteract river current once outside the encroaching salt wedge, and Crisp and Costlow (1963) have noted that



FIGURES 8–10. Opercular valves of *Balanus eburneus* Gould, CAS locality 42617, St. Georges Island, Bermuda, height of scuta and tergum 7.5 mm. FIGURES 11–15. *Balanus eburneus* Gould, CAS locality 42618, Eniwetok, Marshall Islands. Figures 11 and 13, scutum, height 4 mm.; figures 12 and 14, terga, height 4 mm.; figure 15, labrum, ×100.

larval swimming ability is greatly decreased in lowered salinity. In pumped irrigation systems, however, weak swimming larvae can be swept up from river channels and carried into normally unattainable environments. Whether



Figures 16–20. *Creusia domingensis* Des Moulins, CAS locality 42616, Bermuda. Figures 16–17, terga, height 2.5 mm., and figures 18–19, scutum, height 2.5 mm.; figure 20, shell in *Porites astreoides,* greatest diameter of orifice 0.9 mm. Figures 21–22. Shell of *Hexacreusia durhami* (Zullo), CAS locality 27229, Panama, greatest diameter 3.5 mm. Figure 21, uncoated shell showing radii; figure 22, shell coated with ammonium chloride to show external sculpture (apex of rostrum is damaged).

or not flow reversal is an adequate explanation for these unusual occurrences, the possibility remains that barnacles may pose serious fouling problems in irrigation systems.

Creusia domingensis Des Moulins, 1866.

(Figures 16–20.)

A coral-inhabiting barnacle of the genus *Creusia* Leach was also found by Mrs. Gordon in Bermuda in 1967. The specimens are in two small heads of the

coral *Porites astreoides* (Lamarck). The larger coral fragment, measuring about seven centimeters in greatest diameter, contains eleven barnacles, and the smaller, measuring about four centimeters, harbors three individuals.

These barnacles were identified through the kindness of Mr. Arnold Ross of the Natural History Museum, San Diego, who is presently preparing a monographic study of coral-inhabiting balanids. He indicated that they probably represent *Creusia domingensis*; a species originally described in *P. astreoides* from Port-au-Prince, Haiti (Des Moulins, 1866), but which has gone unnoticed since that time. Further examination of specimens of *P. astreoides* in the collections of the California Academy of Sciences (CAS) and of the University of California Museum of Paleontology, Berkeley (UCMP) disclosed additional localities for *C. domingensis* from the vicinity of Biscayne Bay, on the east coast of Florida (CAS locality no. 42265) and from the Dry Tortugas, off southern Florida in the Gulf of Mexico (UCMP locality nos. A-8146, A-8149, B-3717).

Previously, coral barnacles have been reported from the eastern Gulf of Mexico and the West Indies in the Tropical Atlantic region. The discovery of *C. domingensis* in the Bermudas and in southern Florida thus significantly increases the known range both of this little known species and of coralophilous balanids as a group.

Hexacreusia durhami (Zullo, 1961).

(Figures 21–22.)

This six plated coral barnacle was originally described as a species of *Balanus* Da Costa and placed in a new subgenus, *Hexacreusia* Zullo (Zullo, 1961). It was found in late Pliocene, Pleistocene, and Recent specimens of the coral *Porites californica* Verrill from various localities in the Gulf of California, and was later reported in extant specimens of the same coral from the Tres Marias Islands, Mexico, just south of the Gulf of California by Ross (1962).

Although *Hexacreusia* is related to *Balanus*, and especially to the subgenus *Armatobalanus* Hoek, it is more closely allied to the genera *Creusia* Leach and *Pyrgoma* Gray, with which it shares a cup-formed basis, "creusioid" rather than "balanoid" opercular valves, and an obligate coralophilous habitat. For these reasons, *Hexacreusia* is removed from the genus *Balanus* and raised to generic rank.

It was noted earlier (Zullo, 1967) that certain specimens included by Darwin (1854) in his original description of the Australasian species *Balanus allium* were, in fact, *Hexacreusia durhami*. These barnacles were in a coral from Hugh Cuming's collection purported to be from Australia, but which is most probably *Porites californica* from the Pacific Coast of tropical America. As Cuming had spent some time in Central America, but had never traveled

north of the Gulf of Fonseca, Honduras, it was suggested that Darwin's specimens came from an area south of its present-known range.

Confirmation of the presence of *Hexacreusia durhami* in Central America is based on the recent acquisition of two lots from Panama. A beachworn piece of *Porites californica* collected by Dr. Leo G. Hertlein of the California Academy of Sciences on December 22, 1931, at Bahía Honda, Veragua, Panama (CAS-Geology locality no. 27229) contains three shells of *Hexacreusia durhami* without opercular valves. The second lot, made available by Professor J. Wyatt Durham of the University of California Museum of Paleontology (UCMP), consists of about two dozen specimens in a large fragment of a *Porites* questionably identified as *P. lobata* (Dana). The coral was collected by Dr. Peter W. Glynn of the Smithsonian Tropical Research Institute (Canal Zone, Panama) from depths between 10 and 20 feet off the Las Secas Islands, Golfo de Chiriquí, Panama (UCMP locality no. D-4138). These barnacles were alive when taken and still retain opercular valves and bodies, although the latter are unsuitable for dissection because of bleaching and drying during processing of the coral.

Hexacreusia durhami is probably present in *Porites* throughout the Panamic Province, but apparently is absent from the faunas of offshore Eastern Pacific islands. Extensive examination of hermatypic corals from the Galápagos Archipelago, Cocos Island (Costa Rica), and Clipperton Island has failed to yield coral barnacles, although a second species, to be described at a later date, has been discovered in ahermatypic corals from deeper water (90 meters) in the Galápagos.

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